

- 1 1. A method of forming a shell on a template, comprising:
2 immersing the template in a slurry, the slurry comprising
3 a plurality of colloidal particles; and
4 a sufficient quantity of salt to impart an effective charge to the
5 colloidal particles;
6 applying a voltage to the template, thereby causing the charged colloidal
7 particles to be deposited on the template to form a green shell; and
8 sintering the green shell to form a solidified shell having greater mechanical
9 integrity than the green shell.
- 10 2. The method of claim 1, wherein the template comprises a conductive material.
- 11 3. The method of claim 1, wherein the template comprises a conductive coating.
- 12 4. The method of claim 3, wherein the conductive coating is a sputtered coating.
- 13 5. The method of claim 1, wherein the slurry is nonaqueous.
- 14 6. The method of claim 5, wherein the slurry has a dielectric breakdown voltage
15 greater than about 50 VDC.
- 16 7. The method of claim 5, wherein the slurry comprises a material selected from
17 the group consisting of butanol, methanol, ethanol, and propanol.
- 18 8. The method of claim 1, wherein the colloidal particles comprise a material
19 selected from the group consisting of silica, glass, alumina, silicon nitride,
20 silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum and
21 titanium.
- 22 9. The method of claim 1, wherein the colloidal particles have an average
23 particle size of less than 75 μm .
- 24 10. The method of claim 1, wherein the colloidal particles have an average
25 particle size of less than 40 μm .

- 1 11. The method of claim 1, wherein the colloidal particles have an average
2 particle size of less than 10 μm .
- 3 12. The method of claim 1, wherein the colloidal particles have an average
4 particle size of less than 1 μm .
- 5 13. The method of claim 1, wherein the colloidal particles have an average
6 particle size of less than 100 nm.
- 7 14. The method of claim 1, wherein the colloidal particles have an average
8 particle size of less than 10 nm.
- 9 15. The method of claim 1, wherein the salt is selected from the group consisting
10 of sodium chloride, potassium chloride, rubidium chloride, cesium chloride,
11 zinc chloride, and potassium carbonate.
- 12 16. The method of claim 1, wherein the salt is a metal salt.
- 13 17. The method of claim 16, wherein the metal salt is a halide or a carbonate.
- 14 18. The method of claim 1, wherein the salt is an alkyl halide.
- 15 19. The method of claim 1, wherein the salt is present in a concentration of 5% by
16 weight or less.
- 17 20. The method of claim 1, wherein the salt is present at a concentration in the
18 slurry that is at or below its solubility limit.
- 19 21. The method of claim 1, wherein the applied voltage is about 100 volts.
- 20 22. The method of claim 21, wherein the applied voltage produces a current of
21 about 3-5 mA.
- 22 23. The method of claim 1, wherein the green shell has a pore fraction not greater
23 than 40% by volume.

- 1 24. The method of claim 1, wherein the green shell has a pore fraction not greater
2 than 30% by volume.
- 3 25. The method of claim 1, further comprising drying the green shell prior to
4 sintering.
- 5 26. The method of claim 1, further comprising:
6 after immersing the template and applying a voltage, immersing the template
7 in a second slurry comprising a second plurality of colloidal particles;
8 and
9 applying a second voltage to the template to cause the second plurality of
10 colloidal particles to be deposited on the green shell to increase its
11 thickness.
- 12 27. A method of producing a desired article, comprising:
13 providing a template having a predetermined shape;
14 depositing an investment mold on the template, wherein depositing comprises:
15 immersing the template in a slurry, the slurry comprising a plurality of
16 colloidal particles and a sufficient quantity of salt to impart an
17 effective charge to the colloidal particles;
18 applying a voltage to the template, thereby causing the charged
19 colloidal particles to be deposited on the template to form a
20 green shell; and
21 sintering the green shell to form the investment mold;
22 removing the template; and
23 casting the desired article in the investment mold.
- 24 28. The method of claim 27, wherein the template comprises a conductive
25 material.
- 26 29. The method of claim 27, wherein the template comprises a conductive coating.
- 27 30. The method of claim 29, wherein the conductive coating is a sputtered coating.

- 1 31. The method of claim 27, wherein the slurry is nonaqueous.
- 2 32. The method of claim 31, wherein the slurry has a dielectric breakdown voltage
3 greater than about 50 VDC.
- 4 33. The method of claim 31, wherein the slurry comprises a material selected from
5 the group consisting of butanol, methanol, ethanol, and propanol.
- 6 34. The method of claim 27, wherein the colloidal particles comprise a material
7 selected from the group consisting of silica, glass, alumina, silicon nitride,
8 silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum and
9 titanium.
- 10 35. The method of claim 27, wherein the colloidal particles have an average
11 particle size of less than 75 μm .
- 12 36. The method of claim 27, wherein the colloidal particles have an average
13 particle size of less than 40 μm .
- 14 37. The method of claim 27, wherein the colloidal particles have an average
15 particle size of less than 10 μm .
- 16 38. The method of claim 27, wherein the colloidal particles have an average
17 particle size of less than 1 μm .
- 18 39. The method of claim 27, wherein the colloidal particles have an average
19 particle size of less than 100 nm.
- 20 40. The method of claim 27, wherein the colloidal particles have an average
21 particle size of less than 10 nm.
- 22 41. The method of claim 27, wherein the salt is selected from the group consisting
23 of sodium chloride, potassium chloride, rubidium chloride, cesium chloride,
24 zinc chloride, and potassium carbonate.
- 25 42. The method of claim 27, wherein the salt is a metal salt.

- 1 43. The method of claim 42, wherein the metal salt is a halide or a carbonate.
- 2 44. The method of claim 27, wherein the salt is an alkyl halide.
- 3 45. The method of claim 27, wherein the salt is present in a concentration of 5%
4 by weight or less.
- 5 46. The method of claim 27, wherein the salt is present at a concentration in the
6 slurry that is at or below its solubility limit.
- 7 47. The method of claim 27, wherein the applied voltage is about 100 volts.
- 8 48. The method of claim 47, wherein the applied voltage produces a current of
9 about 3-5 mA.
- 10 49. The method of claim 27, wherein the green shell has a pore fraction not
11 greater than 40% by volume.
- 12 50. The method of claim 27, wherein the green shell has a pore fraction not
13 greater than 30% by volume.
- 14 51. The method of claim 27, further comprising drying the green shell prior to
15 sintering.
- 16 52. The method of claim 27, further comprising:
17 after immersing the template and applying a voltage, immersing the template
18 in a second slurry comprising a second plurality of colloidal particles;
19 and
20 applying a second voltage to the template to cause the second plurality of
21 colloidal particles to be deposited on the green shell to increase its
22 thickness.
- 23 53. A method of producing a desired article by investment casting, comprising:
24 providing a master template having a predetermined shape;

- 1 using the master template to produce a transfer mold having a shape
2 complementary to the master template, wherein the transfer mold
3 comprises a flexible material;
4 molding a sacrificial template in the transfer mold, the sacrificial template
5 comprising a material that can be melted, burned, or leached;
6 depositing an investment mold on the sacrificial template, wherein depositing
7 comprises:
8 immersing the template in a slurry, the slurry comprising a plurality of
9 colloidal particles and a sufficient quantity of salt to impart an
10 effective charge to the colloidal particles;
11 applying a voltage to the template, thereby causing the charged
12 colloidal particles to be deposited on the template to form a
13 green shell; and
14 sintering the green shell to form the investment mold;
15 removing the sacrificial template by melting, burning, or leaching, without
16 damaging the investment mold; and
17 casting the desired article in the investment mold.
- 18 54. A casting mold, comprising:
19 a hollow shell comprising a plurality of partially or fully sintered particles and
20 a measurable quantity of salt residue.
- 21 55. The casting mold of claim 54, wherein the particles comprise a ceramic
22 material.
- 23 56. The casting mold of claim 54, wherein the partially or fully sintered particles
24 have an average particle size of less than about 75 μm .
- 25 57. The casting mold of claim 54, wherein the partially or fully sintered particles
26 have an average particle size of less than about 40 μm .
- 27 58. The casting mold of claim 54, wherein the partially or fully sintered particles
28 have an average particle size of less than about 10 μm .

- 1 59. The casting mold of claim 54, wherein the partially or fully sintered particles
2 have an average particle size of less than about 1 μm .
- 3 60. The casting mold of claim 54, wherein the partially or fully sintered particles
4 have an average particle size of less than about 100 nm.
- 5 61. The casting mold of claim 54, wherein the partially or fully sintered particles
6 have an average particle size of less than about 10 nm.
- 7 62. The casting mold of claim 54, wherein the salt residue is selected from the
8 group consisting of sodium chloride, potassium chloride, rubidium chloride,
9 cesium chloride, zinc chloride, and potassium carbonate.
- 10 63. A casting mold, produced by:
11 immersing at least a first portion of a template in a first slurry, the first slurry
12 comprising
13 a plurality of colloidal particles; and
14 a sufficient quantity of salt to impart an effective charge to the
15 colloidal particles;
16 applying a voltage to the template, thereby causing the charged colloidal
17 particles to be deposited on the template to form a green shell about at
18 least the first portion of the template; and
19 sintering the green shell to form the casting mold having greater mechanical
20 integrity than the green shell.
- 21 64. The casting mold of claim 63, wherein the colloidal particles comprise a
22 material selected from the group consisting of silica, glass, alumina, silicon
23 nitride, silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum
24 and titanium.
- 25 65. The casting mold of claim 63, wherein the colloidal particles have an average
26 particle size of less than about 75 μm .

- 1 66. The casting mold of claim 63, wherein the colloidal particles have an average
2 particle size of less than about 40 μm .
- 3 67. The casting mold of claim 63, wherein the colloidal particles have an average
4 particle size of less than about 10 μm .
- 5 68. The casting mold of claim 63, wherein the colloidal particles have an average
6 particle size of less than about 1 μm .
- 7 69. The casting mold of claim 63, wherein the colloidal particles have an average
8 particle size of less than about 100 nm.
- 9 70. The casting mold of claim 63, wherein the colloidal particles have an average
10 particle size of less than about 10 nm.
- 11 71. The casting mold of claim 63, wherein the salt is selected from the group
12 consisting of sodium chloride, potassium chloride, rubidium chloride, cesium
13 chloride, zinc chloride, and potassium carbonate.
- 14 72. The casting mold of claim 63, wherein the salt is a metal salt.
- 15 73. The casting mold of claim 72, wherein the salt is a halide or a carbonate.
- 16 74. The casting mold of claim 63, wherein the salt is an alkyl halide.
- 17 75. The casting mold of claim 63, wherein the green shell has a pore fraction not
18 greater than 40% by volume.
- 19 76. The casting mold of claim 63, wherein the green shell has a pore fraction not
20 greater than 30% by volume.
- 21 77. The casting mold of claim 63, wherein the green shell comprises a plurality of
22 layers of particles, and wherein adjacent layers of particles differ in size
23 distribution or in composition.

- 1 78. The casting mold of claim 63, further produced by, before sintering the green
2 shell:
3 immersing the template in a second slurry comprising a plurality of colloidal
4 particles; and
5 allowing the slurry to dry, thereby causing the colloidal particles to be
6 deposited on a second portion of the template and the green shell to
7 form a second green shell.